PART 4B

GENERAL REQUIREMENTS - INSTRUMENTATION CONTROL AND AUTOMATION

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4.1 Introduction

This part covers the general requirements for the design, supply, installation, inspection and testing of the instrumentation, Control and Automation (PLC based SCADA system inclusive of wired and wireless communication system) and associated plant and materials.

4.2 Reference Standards

Unless otherwise approved, instrumentation shall comply with relevant quality standards test procedures and codes of practice collectively referred to as Reference Standards including those listed below in accordance with the requirements detailed elsewhere in this specification.

BS 89-2:1990, EN 60051-2:1989, IEC 60051-2:1984	Direct acting indicating analogue electrical measuring instruments and their accessories.
BS 1042 (Various)	Measurement of fluid flow in closed conduits.
BS 1646-1:1979, ISO 3511/I-1977	Symbolic representation for process measurement control functions and instrumentation. Basic requirements
BS EN 837-1:1998	Pressure gauges. Bourdon tube pressure gauges. Dimensions, metrology, requirements and testing
BS EN 60751:1996, IEC 60751:1983	Industrial platinum resistance thermometer sensors
BS 3680 (Various)	Measurement of liquid flow in open channels.
BS 3693:1992	Recommendations for design of scales and indexes on analogue indicating instruments
BS EN 60770-1:1999, IEC 60770-1:1999	Transmitters for use in industrial-process control systems. Methods for performance evaluation
BS 4675-2:1978, ISO 2954-1975	Mechanical vibration in rotating machinery. Requirements for instruments for measuring vibration severity
BS EN 60584-1:1996, IEC	Thermocouples. Reference tables

60584-1:1995	
BS 5308 (Various)	Instrumentation cables
BS EN 60529:1992	Specification for degrees of protection provided by enclosures (IP code)
BS ISO 11631:1998	Measurement of fluid flow. Methods of specifying flowmeter performance
BS 5863-1:1984, IEC 60381-1:1982	Analogue signals for process control systems. Specification for direct current signals
BS 5863-2:1980, IEC 60381-2:1978	Analogue signals for process control systems. Specification for direct voltage signals
BS EN 60654-1:1993, IEC 60654-1:1993	Industrial-process measurement and control equipment. Operating conditions. Climatic conditions
BS 6739:1986	Code of practice for instrumentation in process control systems: installation design and practice
BS EN 60073:2002	Basic and safety principles for man-machine interface, marking and identification. Coding principles for indicators and actuators
BS 1553 (Various)	Specification for graphical symbols for general engineering
ISA-5.1-1984 - (R1992)	Instrumentation Symbols and Identification
ISA-5.4-1991	Instrument Loop Diagrams
ANSI/ISA-7.0.01-1996	Quality Standard for Instrument Air
ANSI/ISA-18.1-1979 - (R1992)	Annunciator Sequences and Specifications
ISA-26-1968	Dynamic Response Testing of Process Control Instrumentation
ISA-37.1-1975 - (R1982)	Electrical Transducer Nomenclature and Terminology
ISA-37.3-1982 - (R1995)	Specifications and Tests for Strain Gage Pressure Transducers
ANSI/ISA-50.00.01-1975 (R2002)	Compatibility of Analog Signals for Electronic Industrial Process Instruments
ANSI/ISA-51.1-1979 - (R1993)	Process Instrumentation Terminology

ISO 9000 and 09004	Quality Systems
IEEE 60587	Power Supply Surge Protection
IEC 61131-3	Programming Languages for Programmable Controllers.
IEC 61158-2	Communication Protocols
ISO 9075 (BS 6964)	Structured Query Language (SQL)
BS 5515	Documentation of Computer Based Systems
BS 7165	Recommendation for Achievement of Quality in Software
BS EN 50081	Electromagnetic Compatibility
ISO 3511	Process measurement control functions - instrumentation symbolic representation.
ISO-OSI	7 Layer Communication Model
IEEE 472-1974	Surge protection.
IEC-8705101	Modbus Protocol Conversion

4.3 Statement of Compliance

The Contractor shall provide a list of the reference standards used and shall provide a compliance/non-compliance statement during FDS submission once the contract has been awarded.

All standards which the Contractor intends to use but which are not part of the above Standards or other listed Reference Standards, shall be submitted to the Engineer for consent before any design against that standard proceeds.

4.4 Qualification Criteria for Instrumentation vendor.

All Manufacturers shall be operating under an accredited ISO 9001 or above Quality System.

The instrumentation equipment supplier should have minimum 15 years of experience in India in the field of instruments supply and service. They should have branch locally for service support at Bangalore.

All hardware and software proposed shall have been successfully used in a similar waste water application for a period of at least five (5) years and be from established and reputable suppliers.

4.5 Documents to be submitted during Bid Submission

1. Include a complete Table of Conformance to each and every reference standards or part of the specifications. Use a chart format with specification part identified, indicate whether each part is in compliance, a deviation or an exception to the specific part. If an exception or deviation, include a narrative description as to how the deviation or exception can benefit the end-user of the system over that item specified.

4. Provide an equipment list with descriptive literature for the proposed system. Included on the list shall be all major hardware items. List shall include as a minimum, the manufacturer, the quantity provided, and model numbers for each. Technical schedules for Instruments, PLC & SCADA,ODMS shall be duly filled in with relevant details.

The Contractor shall provide the above required details/documents during the bid submission. Failure to submit even one of the above will be treated as a non-responsive bid and lead to technical rejection of the bid. Contractor shall note the importance of this obligation.

4.6 General Submissions

The Contractor shall make submissions to the Engineer of all design drawings, schedules and complete documentation on spare parts relating to instrumentation to be provided under this Contract.

These submissions shall include, where relevant, the following:

4.7 Instruments and ancillaries

4.7.1 General

All instruments, gauges and control equipment which perform similar duties shall be of uniform type and manufacture throughout the Works in order to facilitate maintenance and the stocking of spare parts.

All equipment shall be fully tropicalised and suitable for the worst environmental operating conditions. Panel-mounted instruments shall be of the electrically operated flush mounted type and shall have damp-proof and dust-proof cases.

Instruments mounted outside instrument panels shall have weatherproof and dust proof cases. Instrument cases shall be of corrosion-resistant material or finish.

Instrument screws (unless forming part of a magnetic circuit) shall be of brass or bronze. Access to terminal compartments of instruments mounted outside panels or other enclosures shall not expose any working part. Moving parts and contacts shall be adequately protected from the ingress of dust. Where applicable instruments shall be easily withdrawable from its housing for maintenance without interrupting its signal.

Unless otherwise specified, instruments shall be finished in the manufacturer's standard colour. Instrument dials shall be of such material that no peeling or discolouration will take place with age under tropical conditions.

Plant-mounted indicators and gauges shall be sized to give full legibility when viewed from a position with convenient and easy access or from the point at which any operation requiring observation of the gauge is performed. The minimum diameter for any gauge shall be 150mm except where forming part of standard instruments and accessories such as air-sets.

Dials and bezels shall be of bronze and internal components shall be of stainless steel, bronze or other corrosion-resistant material.

Unless otherwise specified, all functions shall be transmitted electrically and all analogue signal-transmission systems shall be in accordance with BS 5863: Part 1 or equivalent and shall use a signal of digital or 4mA to 20mA dc. Where possible, measuring systems shall be designed so that any necessary power supply is taken from the appropriate instrument panel.

Transmitting devices shall have integral indicators to monitor the output signal or connections suitable for use with a portable test meter, and shall be capable of meeting the performance requirements specified in the appropriate part of BS EN 60770-1or equivalent. For the important and critical processes the transmitting devices, such as pressure, temperature and level gauges, shall have a reference gauge installed locally for easy reference for the operation and maintenance staff.
The transmitters shall be provided with LCD meters.

Equipment mounted in enclosures shall be suitable for continuous operation at the maximum internal temperature possible in service, due account being taken of internally-generated heat and heat dissipated by other plant. All components

shall be rated adequately and circuits shall be designed so that change of component characteristics within the manufacturers' tolerances shall not affect the performance of plant. All equipment shall be designed to operate without forced (or fan) cooling.

Equipment provided with anti-condensation heaters shall be capable of operating without damage if the heaters are left on continuously. Unless provided with unalterable factory configured ranges, measuring instruments shall have zero and span adjustment.

Field mounted instruments shall be mounted such that they are easily viewable and easily accessible for maintenance.

Instruments not mounted in panels shall be supplied complete with all brackets, stands, supporting steelwork and weatherproof enclosures (separate from the instrument cases) necessary for securing them in their working positions and affording complete protection at all times including periods of servicing, adjustment, calibration and maintenance.

Each installation shall incorporate a valve and pipework for obtaining a sample representative of the fluid at the position of the permanent meter and drain. If the measuring and sampling points are remote from each other, the test and sample facilities shall be provided at both points.

In order that maintenance and inspection may be carried out safely and conveniently instruments mounted in elevated and open work areas shall be provided with safety ladders and a sufficiently sized working platform with sun shading.

4.7.2 Indicating Instruments and Meters

All instruments and meters shall be flush mounted and generally of the same pattern and appearance throughout and those which perform similar duties shall be of uniform type and manufacture.

Indicating instruments shall be fitted with an externally accessible zero adjuster. They shall have no parallax error and their normal maximum reading shall be approximately 60% full scale deflection.

Ammeters in motor starter circuits shall be capable of withstanding the starting current and shall have a compressed overload scale. The ammeter shall have an adjustable and sealable red pointer set to indicate normal full load current. The

ammeter physical size shall be in keeping with the size of the starter concerned. The minimum size to be used is 0.25 DIN.

Indicating instruments shall comply with IS 1248, BS 89 or IEC 60051 and shall be of industrial grade accuracy.

Kilowatt-hour meters shall comply fully with IS 722 or BS 5685 Class 2 and shall have industrial grade accuracy (±2.5%). Three element units shall be used for 3 phase 4-wire systems. Two element units shall be used for 3 phase, 3-wire systems.

4.7.3 Indicator Lights

Indicator lights shall be not less than 20 mm diameter and shall be panel mounted types with metal bodies adequately fastened so that the lamps shall be capable of replacement from the front of the apparatus without disturbance to the lampholder or panel wiring. Lampholders shall be keyed into panels to prevent rotation. Lens colours shall comply with BS EN 60037 as follows:

- power on white*
- running - green
- tripped/alarm red
- status (open, closed, etc) blue
- ready to start blue
- warning (no imminent danger) amber

Note: *white may be used where doubt exists as to which other colour to use.

The lights shall be under-run to give long life either by use of a resistor to limit voltage to 90% normal value or by using higher voltage lamps.

The indicating lamps on control panel shall be cluster of LED's.

4.7.4 Pushbuttons

Colours of pushbuttons shall generally comply with IS 6875, BSEN 60947, 60037 or IEC 60073 and in particular shall be as follows:

- stop, emergency stop red
- start green
- jogging/inching black
- reset (when not also acting

	as a stop)	blue	
-	lamp test	blue	
-	override/alarm accept		yellow

4.8 Cabling

4.8.1 Instrumentation cabling

Cables from conventional measuring transmitters and analogue process controllers, such as digital or 4mA to 20mA dc output from a constant-current source, (hereinafter referred to as high-level signals) shall be polyethylene or PVC insulated with stranded conductors and laid up as twisted pairs with one twist per 30mm approx. Each cable shall have an overall screen of braided copper or mylar backed aluminium foil giving a minimum coverage of 85%, a steel wire armouring insulated from the screen and from any ducting and an overall PVC sheath. For runs exceeding 30 metres or for all inputs to a data logger, computer or microprocessor, multi-core cables shall have an individual screen of braided copper or mylar-backed aluminium foil for each signal pair. The minimum conductor size shall be 24/0.2mm but shall be of greater cross-sectional area if required for the satisfactory operation of associated plant. Cables for intrinsically safe systems shall comply with BS 5308 and the relevant certificate.

Cables from strain gauges, analysers and the like, such as 0 to 100mV (hereinafter referred to as low-level signals — see also below) shall be as specified above and shall have an individual screen for each signal pair.

Cables from indicating devices to alarm or tripping circuits shall be as specified above for high-level signals but shall use cables, cable trays, ducts and conduit separate from those for other high-level circuits.

Cables for high-level signals, low-level signals, resistance thermometers and thermocouples shall be segregated from each other and each shall be separated from cables for power, communications and other electrical services. Other cables run in the vicinity of instrumentation cables shall be twisted at the rate of one twist per 50mm approximately and shall be separated from instrumentation cables by a distance of not less than 300mm.

Initiating devices for plant protection and personnel safety shall be connected by individual cables direct to the tripping or safety device and shall not be

routed via any intermediate junction, marshalling box, cabinet, relay or similar. The outer sheaths of such cables shall be coloured orange.

4.8.2 Telemetry cabling

Telemetry cabling between a master station and an outstation, unless otherwise specified, shall consist of a minimum of 6 signal pairs, of which two pairs shall be allocated to the telemetry system, one pair shall be allocated to a speech circuit and three pairs shall be spare. Each conductor shall be multi-stranded with an equivalent diameter of not less than 0.9mm. Conductors shall be laid up in starquad formation. The dc resistance of any pair of conductors shall not exceed 88 ohms per loop mile at 10°C and the difference between the resistances of the conductors of any pair shall not exceed 0.5% of the loop resistance of that pair.

Telemetry cables shall be designed for burying in water-logged ground.

Conductors shall be plain annealed copper with aluminium/polythene laminate sheath moisture barrier, copper or brass tape pest barrier, single galvanised steel wire armour and overall polythene sheath. The cable shall have a solid filling of petroleum jelly.

The characteristic impedance of each signal circuit shall have a nominal value of 600 ohms at 800Hz and the circuits shall be suitable for signal input levels of between −30dbm to +4dbm (0dbm = 1mW into a load of 600 ohms). The overall attenuation between the terminations of any circuit at the mean frequency of the band width specified elsewhere shall not exceed 20dbm and the attenuation at any two frequencies within this band width shall not differ by more than 6dbm. The transmission time for any two frequencies within the band width specified elsewhere shall not differ by more than 1 / (4 % B) seconds, where B is the transmission speed in bauds, as specified elsewhere.

The signal-to-noise ratio within the bandwidth specified elsewhere shall be better than 12db. The frequency of any received signal shall not differ from the frequency of the corresponding transmitted frequency by more than 1% of the transmission speed in bauds specified elsewhere.

Loading coils as necessary to meet the performance requirements detailed herein shall be supplied and installed at equally-spaced points.

(a) Fiber optic cable

To facilitate the proper and efficient co-ordination of the Works the Contractor shall sublet all Cabling Works to one Sub-Contractor who has proven and successful experience in fiber optic cable installations on projects similar to the one now proposed.

If cable sizes are not indicated on Drawings or in schedules, determine the correct size based on total end to end signal attenuation not to exceed 40 dB, including all splices and termination losses, and after taking into consideration.

a) Type of fiber
b) Ambient conditions
c) Method of installation
d) The disposition of each cable relative to others

All cables and wires shall be suitable for installation and continuous services in the ambient conditions described elsewhere in this document.

Shop Drawings and Product Data shall be submitted for the approval of the Engineers as follows;

- Submit full technical details of each type of cable proposed.
- Submit copy of test certificates from the manufacturer or an independent testing authority confirming that cables comply with the specification.
- Submit exact route of the cable run and relevant Sections in the shop drawings.

Each drum length of cable shall be allotted a distinct and separate reference number. This number shall appear on the test certificate covering the respective length of cable and shall also be clearly marked on the cable drum.

The Contractor shall advise the Engineer upon delivery to site of each drum length, quoting the reference number, the test certificates shall be handed to the Engineer for examination and approval.

All cables shall be delivered to site with the manufacturer seals, labels or other proof of origin intact. These labels and seals shall not be removed until the cable is required for use and shall be retained for inspection by the Engineer.

The Contractor shall be responsible for the off-loading and handling of the cables on site, and shall ensure that cables are delivered to site on drums and properly protected against mechanical damages. Where lengths are cut from cables, the open ends shall be sealed.

The contractor shall be aware of the need to supply and install all cables for this Contract which are most suitable for the special environmental conditions prevailing in this project.

The cable shall comprise 8 fibers, loose tube, two fibers per tube with central 1.5 mm nominal steel central strength member, moister barrier, steel tape armored in continuos lengths up to a maximum of 6.0 km or as dictated by cable joint chamber locations and route survey.

Single Mode	
Type of fiber	Single mode, doped silica
Core Diameter	9.0 ± 0.5 micro m
Cladding Dia	125 ± 2.0 micro m
Coating (outer) Diameter	250 ± 15 micro m Material UV curable acrylate
Numerical aperture	0.11 micro m
Attenuation	<0.4 dB/km @ 1300 nm <0.2 dB/km @ 1500 nm
Bandwidth	1000 MHz @ 1300 nm
Chromatic Dispersion	3.5 ps/nm x km @ 1300 nm 20 ps/nm x km @ 1500 nm
Operating temperature range	-30 to +80 deg. C
Crush resistance	>200N/cm
Weight	500 kg/km (maximum)
Tensile strength	2000 N (minimum)
Multi mode	
Type of fiber	Multi mode, doped silica
Core Diameter	62.5 ± 3.0 micro m
Cladding Diameter	125 ± 2.0 micro m
Coating (outer) Dia	250 ± 15 micro m Material UV curable acrylate
Numerical aperture	0.275 $\pm$ 0.15 micro m
Attenuation	<3.2 dB/km @ 1300 nm <0.9 dB/km @ 1500 nm
Bandwidth	500 Mhz x km @ 1300 nm
Operating temperature range	-30 to +80 deg. C
Crush resistance	>200N/cm
Weight	500 kg/km (maximum)
Tensile strength	2000 N (minimum)

4.8.3 Cable termination boxes

Cable termination boxes shall have double-ended screw terminals with removable links to facilitate core isolation during testing. Each box shall contain sufficient terminals for every conductor plus 20% spare terminals. Cable termination boxes shall have cable sealing chambers and insulated glands with earthing terminals so that the armouring may be earthed or isolated from earth, as circumstances dictate.

Termination boxes for use within buildings shall be of sheet steel with hinged or removable front covers. All other termination boxes shall be cast steel or heavy gauge sheet steel construction giving protection to IP55. All termination boxes shall be hot-dip galvanised or approved equivalent finish. Each terminal box shall have a removable, un-drilled gland plate and the Contractor shall supply and fit the requisite number of cable glands.

At each cable termination box, each cable core (including spares) shall be identified by a numbered slip-over type collet. The numbering for a particular cable core shall be the same throughout its length.

Cable joints shall be at points approved by the Engineer.

Each cable joint shall be of the straight-through type. The conductors shall be ferrule-jointed with the insulation maintained by heat-shrink sleeving. Joint closure shall be made with epoxy resin and the completed joint shall be impervious to water if submerged or in waterlogged ground. If cast iron joint boxes be used, they shall be provided with cable glands and, after installation and testing, shall be covered with Densomastic HD compound or equal; so that all sharp corners, bolts and projections are moulded to a smooth surface. Two lappings of Densopol grade ZN 50mm tape, or equal, shall then be applied overall. Jointing shall be carried out on each conductor, including any provided in excess of the minimum quantity specified. All materials and things of every kind required for the cabling jointing shall be provided by the Contractor.

4.8.4 Cable labeling

At each end of each cable, in a uniform and visible position, a label shall be fixed on the cable to indicate the site cable number and route, and the number and size of conductors. Labels shall be made of brass, aluminium, lead or copper strip, engraved and retained by suitable non-rusting or non-corrodible binding wire passing through two fixing holes, one at either end of the label. If the cable gland is not normally visible, then the label shall be fixed inside the panel by means of screws.

Three-phase power cable cores shall be identified A, B, C or colour-coded red, yellow, blue so that the correct three-phase sequence is preserved throughout the system. Single-phase power cable cores shall be colour-coded red and black.

Control cables shall have individual cores identified by means of suitable permanent ferrules bearing the same number at both ends. Core identification shall occur at every point of termination using an approved system of colour-coded ferrule markers. The size of these ferrule markers shall be such as to match the overall diameter of conductor plus insulation. Numbering shall read from the termination upwards on all cores.

Each cable and core shall bear the same number at both ends of the cable and core respectively.
(a) Power terminations — colour, number or letter.
(b) Control terminations — letter or number or both.

4.8.5 Cable terminations

All PVCSWAPVC, PVCPVC and XLPESWAPVC cables shall be terminated with mechanical glands which shall comply with BS 6121. They shall seal the inner and outer cable sheaths against ingress of dirt and moisture and provide adequate mechanical support. Each cable gland shall be protected by corrosion-resistant molded PVC hoods, covering the entire assembly from the overall sheath to the gland neck.

Glands for armoured cables shall provide a positive armour clamp to the enclosure so that no tension is applied to the termination. The clamp shall also provide a high level of earth continuity and be of adequate size to withstand the full fault current of the system for one second.

All glands shall be provided with an earthing tag. For cables of 4mm² or less, a serrated washer may be used instead for earth continuity.

The cable termination and sealing equipment shall be obtained from the cable manufacturer, or other approved supplier, and shall be purpose-made for the type, size and grade of cable concerned. The application of these materials shall be strictly in accordance with the manufacturer’s instructions.

Through joints shall be permitted only on long cable runs outside buildings. Where such joints are necessary; the cables shall be jointed with epoxy or acrylic resin Cold-setting compound which has been pre-measured and pre-packed ready for use.

The boxes shall be of a split moulded plastic type with filling vents for compound.

Bonding straps shall be fitted with armour clamps across the joint and inspected by the Engineer prior to filling the box with compound. Wrapped pressure type joints shall not be accepted.

Conductor cores shall be jointed number to number or color to color.

4.8.6 Cable installation-general

Cables which are to be run on walls, ceilings or other building structures shall, unless otherwise agreed by the Engineer, be secured on cable trays and ladders or enclosed in conduit or trunking.

Every cable shall be neatly run vertically or parallel to adjacent walls, beams or other structural members. Cables shall not be installed in areas of direct sunlight.

Where this is unavoidable, approved sun shields shall be supplied and installed.

Where the building structure incorporates purpose-built covered duct or trench systems for main cables, instrumentation cables shall be segregated and installed on tray work or otherwise secured to the sides of the duct or trench.

Where the structure incorporates general service ducts or trenches containing pipework, chemical lines and other services, all cabling shall be segregated from the other services and shall be run on the walls unless otherwise agreed by the Engineer.

Cables shall be spaced to prevent interference between power and signal cables, and to avoid unnecessary crossovers.

The spacing of clips, saddles and cleats shall prevent the sagging of the cables during their installed life. The method of fixing clips and the like shall be by means of non-corrodible screws inserted into approved wall fixings, such as rawlplugs.

Cable hangers, cleats, saddles, brackets and similar supporting devices shall be of an approved type and of adequate strength for the cables they are supporting. They shall be treated to withstand Site conditions without

corroding. Self-locking plastic buckle clips and strapping shall not be used. The arrangement and fixing of each cable shall permit the removal and replacement of any cable without disturbance to any other cable or the fixings thereof.

When cables are terminated in any particular item of equipment, special care shall be taken to ensure that the cables finally approach the equipment from a common direction and are individually terminated in an orderly and symmetrical fashion.

Submissions which the Contractor shall submit the following in relation to cable installations in addition to submissions detailed elsewhere in the Specification.

4.8.7 Drawings and schedules:

• Block diagrams to show control cabling systems with each cable and terminal equipment being identified as in the cable schedules.
• Cable route and layout drawings. For those items which are underground, these drawings shall include the following:
• Route plans and sectional views for all cable runs, cable trays, cable ducts and cable trenches;
• The position of all marker posts, joints, draw pits and the like.
• Cable schedules shall detail the cable number, type, voltage, size, route length and number of cores or pairs. Control-cable schedules shall detail the connected and spare core numbers, diagram number for connected equipment, core ferrule and terminal reference number.

4.8.8 Data and calculations:

• Manufacturers' catalogues and data sheets for all cables and fittings. Cable sizing Calculations.

4.8.9 Test certificates:

• Test certificates for all witnessed and routine tests carried out at the manufacturer's works and at Site(calibration).

4.8.10 Cable trays and ladders

Cable tray and cable-support ladders shall be of heavy-gauge galvanised steel and with an overall PVC coating when required to the approval of the Engineer.

Cable tray and ladder systems shall be installed using factory-made supports, joints and junction/bend pieces. Wherever tray and ladder sections are cut and shaped on Site, cut edges shall be dressed and painted with at least two coats of cold galvanising compound or lead-based anti-corrosive paint.

Ladder systems shall be secured to walls and ceilings by pre-formed galvanized interlocking channel.

4.8.11 Flexible conduits

Flexible conduit shall be of the waterproof galvanised type of PVC wire-wound type with cadmium-plated mild steel couplings. Lengths of flexible conduit shall be sufficient to permit withdrawal, adjustment or movement of the equipment to which it is attached and shall have a minimum length of 300mm. Flexible conduit shall not be used as a means of providing earth continuity. A single earth conductor of adequate size shall be installed external to the conduit complete with earth terminations.

Where conversion from rigid conduit to flexible metallic conduit is to be made, the rigid conduit shall terminate in a trough-type box. The flexible conduit shall extend from this box to the equipment; the earth continuity cable shall be secured to the box and to the piece of equipment. The use of lid facing screws and the like will not be permitted. Adaptors shall incorporate a grub screw or a gland to prevent the flexible conduit becoming loose.

4.8.12 PVC conduit

Where galvanised conduit would be liable to corrosion, PVC conduit shall be installed.

PVC conduit shall be of the oval or round high impact non-flame-propagating type as specified and self-extinguishing, to BS EN 61386-21. Surface and concealed installations shall be generally as described for steel conduit.
PVC conduit fittings shall comply with BS 4607. They shall all be white unless specified otherwise.

Jointing shall be carried out using PVC solvent and socketed accessories.

Expansion couplers shall be fitted in straight surface runs every 12m. The free end shall be sealed with non-setting mastic to form a waterproof seal.

Purpose-made bends may be used providing that the cable bending radius is maintained. Cracked or crinkled conduit will be rejected.

The conduit shall be suitable for use in ambient temperatures of between −5°C and +60°C and shall not be installed in areas that receive direct sunlight. A separate protective conductor (earth-continuity conductor) shall be installed.

Adaptable boxes and accessories shall be made from heat-resistant insulating material. The minimum wall thickness of boxes having a nominal internal depth of 16mm or less shall be 1.5mm. For deeper boxes, the minimum wall thickness shall be 2mm. All boxes which are intended to support luminaires or other heat sources shall have either external fixing lugs riveted to the metal inserts or utilise steel insert clips.

4.9 Cable installation methods

4.9.1 General

All cabling installation methods shall be subject to the approval of the Engineer.

4.9.2 Installation directly into the ground

Where cables are buried in the earth, the bottom of the excavated trenches shall be freed of sharp stones and other projections and covered with sand to a depth of 50mm.

Cables shall be unrolled from drums without loops and kinks, and care shall be taken when laying to avoid damage to the outer sheath by drawing over sharp projections.

Cables shall be snaked into the trenches to avoid tension in the cables during backfilling or from subsequent settlement. After laying, cables shall be covered to a minimum depth of 100mm of compacted sand and shall have a layer of protective interlocking concrete cable tiles. The tiles shall be overlaid with marker tape.

When cables of different voltages are laid together at the same depth, vertical cable tiles shall be used to segregate the cables.

ICA and communication cables shall be laid not closer than 1000mm to high voltage cables.

A sufficient number of rollers shall be provided so that the cable does not touch the ground or twist during pulling.

4.9.3 Installation in underground ducts

Underground ducts shall be constructed of impact-resistant uPVC and laid at a minimum depth of 500mm (to the duct centre), surrounded by at least 75mm of sieved sand. At road crossings, uPVC ducts of minimum diameter 100mm shall be laid at a minimum depth of 1000mm (to the duct centre). The ducts shall be encased by 150mm concrete on all sides.

When installing cables in ducts, the following measures shall be observed:

- Cables shall be pulled in a straight line;
- Rollers shall be positioned at the edges of drawpits both at the drawing-in and drawing-out points over which the cables shall be drawn;
- uPVC pipes and cable sheaths shall be coated with an approved lubricant;
- Sufficient draw-in points shall be provided and adequate room allowed for installation of cables;
- The pulling rope shall be guided by rollers.

Only one power cable shall be drawn into each duct.

Whenever a duct is laid in the ground, a draw-wire shall be pulled through with at least 1000mm excess at each end and the draw-wire left in position if the duct is not to be used immediately.

4.9.4 Sealing cable entries into buildings

Whenever cables pass through walls below ground level, the point of entry shall be sealed against the ingress of water. This shall be achieved with silicone foam or similar.

All cable entries into a building shall be in ducts and where the cables pass in or out of ducts, together with any spare ducts, the ducts shall be sealed against the ingress of moisture by means of duct stoppers and bituminous compounds or by any other method approved by the Engineer. The stopper shall have a fire resistance of at least 30 minutes.

4.9.5 Marking of underground cables

The location of all underground cables shall be identified by:

• Brass plates fixed to the exterior surface of all walls of buildings 300mm above ground level and directly above the point where cables pass through the wall;
• Marker posts in road verges and the like at intervals of not more than 100m and at all junctions and changes of direction along the route;
• Marker posts at 10m intervals within an enclosed site and at all junctions and changes of direction along the route.
Marker posts shall be of concrete, not less than 200mm high above ground with an inscribed brass or enamel metal plate. The inscription shall indicate the presence of a cable below, the depth, classification and voltage rating.

A drawing or sample of a typical marker post shall be submitted for the approval of the Engineer.

4.9.6 Installation in cable trunking

Cable trunking shall be manufactured from mild steel of not less than 1.25mm and shall be hot-dip galvanised. The Contractor shall ensure that the size of the trunking is adequate for the number of cables to be installed together with 50% spare capacity. Trunking shall have minimum dimensions of 50mm % 50mm.

Segregation of cables shall be carried out if required using continuous sheet steel barriers with the bottom edge welded to the trunking. The trunking shall have two return flanges for rigidity. Where necessary, additional strengthening straps shall be fitted internally. The cover shall overlap the trunking and be made of the same gauge. Fixing screws for covers shall be recessed and be of the self-retaining quick-fix type. All bends, tees and intersections shall be of the gusset type and shall, wherever possible, be purpose-made by the manufacturer and of a matching design to the main trunking.

Cables shall be retained in the trunking when the cover is removed by means of straps. Internal connecting sleeves shall be fitted across joints in the trunking and earth continuity ensured by bonding each section of trunking to a continuous earth wire.

Non-flammable fire barriers shall be inserted where the trunking passes through walls or floors. Conduit connections to trunking shall be made by flanged couplings and male bushes.

Trunking shall be supported at intervals not greater than 2m horizontally or 2.5m vertically.

Crossings over expansion joints shall be made in flexible conduit.

Should it be necessary to cut or drill a section of trunking, the bared ends shall immediately be given a coat of zinc-rich cold galvanising paint.

Cable and trunking runs shall be determined by the Contractor and agreed by the Engineer before any work is started. The run shall be at least 150mm clear of plumbing and mechanical services.

Trunking systems erected outside a building shall be weatherproof.

4.9.7 Installation in troughs and trenches

Where the building structure incorporates purpose-built covered trench systems, power distribution cables may be laid on the floor of the trench. Control and instrumentation cables shall be segregated and installed on supporting steelwork or cable trays secured to the walls of the trench.
Where the building structure incorporates general service trenches containing pipework, chemical lines and other services, all cabling shall be segregated from other services and run on the trench walls. Crossovers shall be kept to a minimum and cabling shall be taken above wet service pipework.

Cable trays shall be of perforated steel with formed flanges and of minimum thickness not less than 1mm for trays up to 100mm width, not less than 1.25mm for trays from 100mm to 150mm width and not less than 1.5mm thickness for trays from 150mm to 300mm width.

Cable-tray supports shall be of sufficient strength to maintain rigid support to the fully-laden cable tray along its entire length. All brackets and tray work shall be suitable for withstanding a temporary weight of 125kg.

Wherever possible, cable trays shall be installed in full lengths without cutting.

Should it be necessary to cut or drill a length of tray, the bared ends shall be dressed and immediately be given a coat of zinc-rich cold galvanising paint. Similarly for PVC-coated trays, the bared end shall be immediately sprayed using a PVC aerosol.

All cables shall be firmly secured to the tray using purpose-made saddles, as approved by the Engineer, together with proprietary cable cleats.

4.9.8 Installation in buildings

Cables required to be run on walls, ceilings, or other structures shall be carried on substantial cleats, either in groups or simply at spacings determined by rating requirements, supported on tray or ladder racks or enclosed in conduit or trunking.

All cables shall be neatly run vertically or parallel to adjacent walls, beams or other structural members.

The spacing of clips, saddles and cleats shall be such as to prevent the sagging of the cables during their installed life. The method of fixing clips and the like shall be by means of non-corrodible screws inserted into approved wall fixings.

Cable hangers, cleats, saddles, brackets and similar supporting devices shall be of an approved type and of adequate strength for the cables they are supporting. They shall be treated to withstand site conditions without corroding. Self-locking plastic buckle clips and strapping shall not be used.

Hangers shall be spaced according to recommendations in the IEE Wiring Regulations. Allowance shall be made for expansion and contraction of the cables.
Cables shall be located between 50mm pegs spaced at 40mm centres across a rung so that a 40mm or 80mm space is maintained between cable centres. Cleats shall be used where the ladder racking is vertical.

Cables shall be run at least 150mm clear of plumbing and below heating and hot water pipework.

4.9.9 Cable installation in conduits

Conduits shall be either galvanised heavy-gauge steel screwed type or light-gauge steel non-screwed type, steel or PVC. Accessories shall either be malleable cast iron or pressed steel.

A space factor of 40% shall not be exceeded and, in any case, conduit shall have a minimum diameter of 20mm. The tubing is to be perfectly smooth inside and out and free from imperfections. Both ends of every length of tubing shall be reamed and all sharp edges removed before erection.

Where conduits converge, adaptor boxes shall be used. Conduits shall be connected by means of male brass bushes and couplings. Where conduits are

greater than 25mm diameter, straight-through joint boxes shall be of the trough type. Where conduit or fittings are attached to equipment casings, the material of the casing shall be tapped for a depth of not less than 10mm or male bushes and flanged couplings may be used.

Hexagonal lock nuts shall be used at running joints. They shall seat firmly and evenly on to mating faces. All function boxes, draw-in boxes, and inspection fittings shall be placed so that the cables can be inspected, withdrawn and re-wired during the life of the installation.

Generally not more than two bends or offsets or one coupling will be permitted without a suitable inspection accessory. Fish wires shall not be left in conduits during erection. The whole of the installation shall be arranged for a loop-in type of system with joints being carried out at switches, isolators or appliance fittings.
Ends of conduits which are liable to be left open for any length of time during building operations shall be plugged to prevent the ingress of dirt and covers shall be fitted on all boxes.

Generally, conduits shall not cross expansion joints of buildings. Where they cannot be installed in any other manner, a galvanised flexible conduit shall be used across the expansion joint. A total of 150mm movement shall be allowed.

4.10 Process Instrumentation

4.10.1 General

Instrumentation system shall be designed, manufactured, installed and tested to ensure the high standards of operational reliability. All electronic components shall be adequately rated and circuits shall be designed so that change of component characteristics shall not affect plant operation.

All instrumentation equipment shall be new, of proven design, reputed make, and shall be suitable for continuous operation. Unless otherwise specified, all instruments shall be tropicalised. The outdoor equipments shall be designed to withstand tropical rain. Wherever necessary space heaters, dust and water proof cabinets shall be provided. Instruments offered shall be complete with all the necessary mounting accessories.

Electronic instruments shall utilise solid state electronic components, integrated circuits, microprocessors, etc., and shall be of proven design.

No custom made hybrid type integrated circuits shall be used.

Unless otherwise stated, overall accuracy of all measurement systems shall be ±1% of measured value, and repeatability shall be ±0.5%.

Unless otherwise specified, the normal working range of all indicating instruments shall be between 30% and 80% of the full scale range.

On resumption of the supply following a power failure the instruments and associated equipment shall start working automatically.

The instruments shall be designed to permit maximum interchangeability of parts and ease of access during inspection and maintenance.

Unless otherwise stated, field mounted electrical and electronic instruments shall be weatherproof to IP-65.

The instruments shall be designed to work at the ambient conditions of temperature, humidity, and chlorine contamination that may prevail but in any case not less stringent than those conditions detailed in the Project Requirements. Instruments shall be resistant to corrosion in the atmosphere in which they are expected to operate.

Lockable enclosures shall be provided for all the field mounted instruments.

All field instruments, and cabinets/panel mounted instruments shall have tag plates/name plates permanently attached to them. Details of proposed inscriptions shall be submitted to the Employer for approval before any labels are manufactured.

All coated parts of sensors shall be made out of non corrosive material capable of working with chlorine content of 5 ppm.

For all instruments installed in the field, surge protection devices (SPD s) shall be provided at both ends of the connecting cable for protection against static discharges / lightning and electromagnetic interference.

Individual pair screened, overall screened, armoured cables shall be used for analogue signals and armoured, overall screened cable shall be used for digital signal cables.

4.10.2 Flow Measuring Systems

Flow measuring system shall consist of flow sensor / transducers, flow computer and flow transmitter.

Flow transducers shall be rugged in construction and shall be suitable for continuous operation. Flow transducers shall have waterproof construction and shall be suitable for installation in underground/above ground pipelines.

To avoid the effects of disturbances in the velocity profile, a straight and uninterrupted run, upstream as well as downstream from the location of the flow sensor shall be provided in accordance with the requirements of the flowmeter manufacturer.

The flow transmitter shall be suitable for field or panel mounting and shall accept an input from the flow sensor. It shall process the input signal and provide 4-20 mA dc output proportional to flow rate. The flow range shall be adjustable.

A zero span adjustment facility shall be provided for flow transmitter and indicator.

Flow measurement shall not be affected by physical properties of sewage viz., temperature, pressure, viscosity, density etc., within given limits. Contractor shall provide compensating electronic circuits if required. The overall accuracy of flow measuring systems shall be at least ±1.0 % of the measured value unless otherwise stated.

(b) Open Channel Flow meter

Open channel flow measuring systems shall consist of level transducer, flow computer and flow transmitter. The level of the fluid in the flume shall be measured by the ultrasonic level transducer. The level measured shall be used along with the physical characteristics of the flume to compute the flow rate.

The level transducer shall be suitable for flange or bracket mounting as required and shall be environmentally protected as per IP65. It shall have ambient temperature compensation and adjustable datum setting facilities.

The design and application of ultrasonic level meters shall take into account the channel construction, the material size, shape, environment, process fluid or material, the presence of foam, granules, size etc.

The installation shall avoid any degradation of performance from spurious reflections, absorption, sound velocity variations, sensor detection area, temperature fluctuations, specific gravity changes and condensation. For application where spurious reflections are unavoidable the control unit shall be provided with facilities for spurious reflection rejection.

The structure required for supporting the level sensor, platform, railings etc shall be in the Contractor's scope.

4.10.3 Level Measuring System

Ultrasonic Level Meters

Ultrasonic level measuring devices applied for level measurement shall comprise a transducer, control unit and remote indicator.

The transducer shall be suitable for flange or bracket mounting as required and shall be environmentally protected to IP 65. It shall have ambient temperature compensation, adjustable datum setting facilities.

The accuracy of the sensor shall be ±0.25% or better.

It shall be programmable with an integral programming keyboard and provide a digital display of the measured variable. It shall be provided with diagnosis facilities and shall provide an isolated 4 to 20 mA dc output signal proportional to the range of measurement.

The design and application of ultrasonic level meters shall take into account the vessel or channel construction, the material, size, shape, environment, process fluid or material, the presence of foam, granules, size etc.

The installation shall avoid any degradation of performance from spurious reflections, absorption, sound velocity variations, sensor detection area, temperature fluctuations, specific gravity changes and condensation. For applications where spurious reflections are unavoidable the control unit shall be provided with facilities for spurious reflection rejection.

If turbulence exists, shielding, stilling tubes or other measures shall be provided to avoid effects on the measurement.

4.10.4 Conductivity Level Switches

The electrodes used for conductivity level switches shall be stainless steel. Single electrode systems (one electrode per holder) shall be used (except where their use is impractical) with insulated electrodes such that only the tip of each electrode is exposed to the liquid at the operating level.

Relay or control units operating with level electrodes shall have adjustable sensitivity. Electrodes for use in fluids of low or variable conductivity shall be fitted with conductivity discs.

Where relay or control units are not mounted in control panels, they shall be provided with surface mounting enclosures with a degree of protection to IP 52 for indoor locations or IP 65 for outdoor locations.

4.10.5 Pressure gauges and transmitters

Pressure gauges shall comply with BS EN 837-1 or equivalent and have concentric scales. For specially arduous duty where the gauge is subject to pressure pulsations and/or vibration, it shall be provided with a glycerine-filled dial and line snubbers shall be used. Bourdon-tube type differential-pressure gauges shall be capable of withstanding full line pressure on any side with the other side vented to atmosphere without damage to or effect on the calibration. No plastic material shall be used in their construction. Internal parts shall be of stainless steel, bronze or approved corrosion-resistant material.

The minimum diameter for round pressure gauges shall be 100mm unless specified otherwise or where the gauge forms part of a standard item of equipment.

Unless specified elsewhere the accuracy for pressure gauges shall be 1% of range, for diaphragm gauges 1% of range and for differential gauges 1.5% of range or better.

Where compensation of more than 2% of the instrument span is needed for the difference in level between the instrument and the tapping point, the reading shall be suitably adjusted and the amount of compensation shall be marked on the dial.

The zero and span of a pressure transmitter shall not change by more than 0.1% of the span per Celsius degree change in ambient temperature. After application for 10 minutes of pressure at 130% of maximum pressure, the change in zero and span shall not exceed 0.1% of the span.

Pressure transmitters shall have an accuracy typically better than 0.1% of span, depending on the application and shall be protected to BS EN 60529: IP 65 standard or higher standard. For transmitters installed in meter chambers liable to flooding or underwater applications, they shall be to BS EN 60529: IP 68 standard and shall operate up to maximum submergence of 20 metres of water.
Pressure transmitters shall provide a digital or 4mA to 20mA dc output proportional to the pressure range.
Pressure gauges and transmitters shall have primary isolating valves, 2 or 3 way valve manifold and vents, in such a way that it has the facility to calibrate the gauges or transmitters without removal.

4.10.6 Strain-gauge pressure transducers and transmitters

Strain-gauge pressure transducers shall use thin film sensors without bonding.

Each instrument housing shall be of all-welded Grade X 4 CrNiMo 17 12 2 stainless steel or equivalent and hermetically sealed. Non-interacting, zero and span adjustments shall be provided on each transducer. The measuring diaphragm shall be isolated from the process fluid by a non-corrodible barrier diaphragm. The mean time between failure for any model of strain-gauge transducer shall be not less than 15 years, and the performance of the measurement system shall be as given below, or higher performance:

- accuracy: ±0.1% of calibrated span, including linearity hysteresis and repeatability;
- repeatability: ±0.05% at maximum span;
- stability: ±0.1% of upper range limit over 6−month period;
- over-pressure: sustain a 400% over-pressure without damage;
- RFI / EMI effect: less than 1% of span with 500MHz at 5W direct contact;
- power-supply variation effect: 0.01% per volt variation.
- load variation effect: ±0.0002% per ohm of loop-resistance variation.
- temperature: −29°C to +82°C range; total thermal error of ±0.75% of span over 0°C to 50°C;
- protection: IP 65.

Strain-gauge transducers which do not have terminals for their cable connection, shall have integral sealed-cable assemblies, installed in conduit and terminated at weatherproof junction boxes, protected to IP 65 each mounted

near to its associated process transmitter. A digital or 4mA to 20mA dc output signal proportional to the transducer range shall be provided.

Strain-gauge pressure transmitters shall be generally as the transducer except that it shall incorporate a waterproof pressure transmitter producing a digital or 4mA to 20mA output signal.

Provision for transducer venting shall be provided.

4.10.7 Analytical Instruments

General:

This section covers individual elements to measure and transmit pH and ORP. Transmitters shall convert the sensor measurement to a 4 to 20 mA dc signal capable of transmission into at least a 500 ohm load at 50 V or less. Power supply shall be 240 Vac, 50 Hz. Reference accuracy of the output signal shall be ± 1 percent of measured span or better. Output signal shall be electronically isolated from ground to permit connection to a receiver with a grounded input. Transmitters shall be provided with an indicating scale having at least a 0.1 meter calibrated length. Operating ambient temperature shall be -5 to + 50 degree C or better. Transmitted signals shall be linear with the measured variable excepting pH which shall be linear with pH.

Sensor Measurement Principles and Features: Each type of sensor shall use the measuring principle and incorporate the features appropriate to it as specified below:

1. pH and ORP sensors shall measure hydrogen ion activity and oxidation-reduction potential respectively in the process medium. The pH sensor shall consist of a glass measuring electrode, a reference electrode, a solution ground and a temperature sensor for compensation in the transmitter. The reference electrode shall be the non flowing type with an electrolyte diffusion rate through a non-reactive porous membrane or plug which shall not require electrolyte refill more often than once per year. ORP sensors shall use the same elements specified for pH sensors except that electrode shall be platinum and no temperature compensation is required. pH and ORP sensor assemblies shall incorporate an integrally mounted preamplifier for the measuring electrode. Sensors shall operate over a temperature range of -,5 to + 1000 C or better.

Construction. Transmitter and sensor enclosures shall be rated NEMA 4 unless explosion proof (XP) is specified on the Schedule. Enclosure materials and finish shall be as specified in the Schedule. If not so specified, they may be the manufacturer's standard which is compatible with the corrosivity of the atmosphere normally in contact with the enclosure. All parts of sensors, their assemblies and supporting parts which are wetted by the process medium shall be constructed of stainless steel and/or plastic unless specified otherwise on the Schedule. When specified on the Schedule, pH and ORP assemblies shall be provided with integrally mounted ultrasonic cleaners.

4.10.8 Total Dissolved Oxygen Monitoring System

The Dissolved Oxygen (D.O) monitoring system shall consist of a sensor, transmitter, indicating converter and electrode cleaning equipment. Accuracy shall be $\pm$ 0.5% full scale for DO, barometric pressure $\pm$ 0.27 kPa and temperature $\pm$ 0.3˚C.

The sensor shall not require zero point calibration and shall last approximately 2 years with a DO level of 3-5 mg/l and 3-5 years with a DO level of 1-2 mg/l. The transmitter shall allow the DO sensor to be fitted without the use of tools. The transmitter shall output a signal proportional to the DO level and measured temperature. The following alarms shall be detected and transmitted.

1) Membrane puncture
2) Depleted or worn out DO sensor
3) System/electronic fault.

The indicating converter shall perform auto calibration of the system and compensate for sensor age, temperature, barometric pressure, relative humidity and liquid salinity. It shall display OD concentration, temperature, sensor lifetime remaining (mg/l x hours or %) and rh selected for calibration.

Construction. The DO sensor shall consist of a prefabricated, disposable, sealed cartridge that slides easily into the transmitter without special tools. Systems that require re-generation (refill of electrolyte and membrane change) will not be acceptable. The sensor shall use the Clark’s principle, with a gold cathode, silver wire anode and a non toxic electrolyte of potassium chloride. The pre-stressed membrane shall be of Teflon and bonded onto the DO sensor.

The transmitter shall be protected to IP 67 and supplied with 6m of cable for connection to a junction box. The converter shall be housed in a NEMA 4 x enclosure and be handrail or panel mounted up to 200m from the sensor

without need for a pre-amplifier. It shall be interchangeable without the need for recalibration or reprogramming of the system by using a sensor specific storing device continuing all settings and calibration.

The sensor and transmitter shall be installed in a self cleaning polystyrene ball float, which shall float on the surface of the water and allow the sensor to be inserted by approximately 125mm into the water. The ball shall be constructed to fit the sensor and transmitter and leave a smooth surface to prevent accumulation of dirt or grease. Constructions where the sensor protrudes will not be acceptable.

4.10.9 Surge Protection Devices

Surge protection devices (SPDs) shall be suitable for withstanding the surge arising out of high energy static discharge / lightning strikes and protect the instrument to which it is connected against damage. SPDs shall provide protection through the use of quick acting semiconductors like Tranzorb, zener diodes, varistors and an automatic disconnect and reset circuit. SPDs shall be passive and shall require negligible power for operation. During the occurrence of a surge it shall clamp on the allowable voltage and pass the excess voltage to the ground. The SPD shall be self resetting to minimise the down time of the measurement loop.
SPD s shall be provided to protect devices transmitting and receiving analogue and digital signals derived from field devices located outdoors.

The surge protection device shall be rated for surge rating of 10 KA.

END of PART-4B